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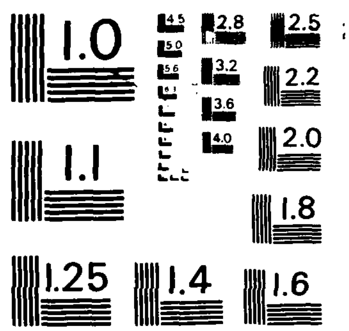

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TITLE: DENSIFIED REFUSE-DERIVED FUELS - OVERVIEW OF PRODUCTION PROCESSES AND COMBUSTION CHARACTERISTICS

AUTHOR: Brian E. Swaidan

DATE: May 1984

SPONSOR: Chief of Naval Material

PROGRAM NO: S0371-01-421E

TECHNICAL NOTE

NAVAL CIVIL ENGINEERING LABORATORY
PORT HUENEME, CALIFORNIA 93043

METRIC CONVERSION FACTORS

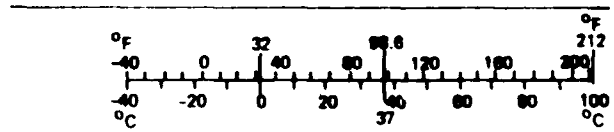
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2,000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1,000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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A literature search was conducted to assess the feasibility of utilizing densified refuse-desired fuel (d-RDF) for the production of hot water and steam in Navy boilers. This report also includes the Air Force efforts in adapting d-RDF technology such as manufacturing processes, storage, shipping, and burning characteristics. Based on experiences in utilizing d-RDF to this date, the technology is available, the burning characteristics are very encouraging, and the economic feasibility would be enhanced

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CONTENTS

INTRODUCTION

The ever increasing demand for energy dictates a judicious use of all available resources. A renewable source of energy is inherent in the large quantities of organic wastes generated daily. These organic wastes, unlike fossil fuels, contain lower concentrations of sulphur and their availability is guaranteed. These wastes, however, are generated in varying ways and compositions, and have high moisture content. In addition, means for shipping, storage, and handling are severely restricted. Proper processing enhances the above properties and renders the product adaptable for burning in Navy coal fired boilers. Densified refuse-derived fuel (d-RDF) is the product of this processing and the subject of this report.

Densified refuse-derived fuel is produced by extracting and densifying into small pellets that fraction of solid waste which possesses the bulk of the fuel value. These dense pellets are then substituted or mixed with coal to produce steam in spreader stoker boilers. The d-RDF manufacturing technology is feasible, but long-term reliability and maintainability of equipment and the consistency of product properties is lacking. While a number of firms have engaged in the production of d-RDF pellets both in this country and abroad, d-RDF pellets are not generally available today. However, a number of firms may be willing to produce pellets if a stable market for the product exists.

The U.S. Air Force is conducting a multi-year evaluation of the merits and problems associated with the use of d-RDF. Their experiences with the handling and firing characteristics of d-RDF at Wright-Patterson Air Force Base (WPAFB), Ohio, are presented. In addition, NCEL has conducted studies aimed at identification and development of fuel specifications, equipment modifications, and operational procedures for the procurement and utilization of d-RDF at Naval shore facilities.

The scope of this report is to survey the various processes that have been under consideration and experimentation and to report on the Air Force experiences in co-burning d-RDF with coal at Wright-Patterson Air Force Base.

d-RDF PRODUCTION TECHNIQUES

Air Force Research

Common to all manufacturing processes for producing d-RDF are those shown in Figure 1. Dumping of incoming waste and cooling the product are also used in certain processes. An Air Force study (Ref 1 and 2) classified d-RDF production processes into two categories. In the first category were existing plants capable of providing fuel suitable for the

boiler facilities at WPAFB, where the fuel was to be used. The second category consisted of processes considered developmental in nature with unknown technical and economic risk.

The development processes classified in the second category are totally unexplored and can be considered as primarily research concept schemes. Their potential impact on d-RDF production in the near future are extremely slight. These were cited in the appendix of the Air Force study (Ref 1) and referred to as research briefs.

Under the first classification, seven systems are cited and are summarized here.

The Maryland Environmental Service Plant operated by Teledyne National. This plant has been supplying d-RDF to WPAFB for testing purposes. Figure 2 shows the basic plant material flow patterns (the aluminum recovery system is not being operated at all). The most significant fact concerning this facility is that it has been on-line more or less continuously for a number of years. The economic feasibility of this facility is not known because of local, state, and government subsidies. Other facts about the d-RDF product are also shown in Figure 2.

Plant capacity for incoming refuse is rated at 1200 tons/day, and the overwhelming majority of this is landfilled. Only a small percentage is processed into d-RDF (approximately 6000 tons from 1975 to the present), and due to the relatively low yield, additional development is warranted. Furthermore, the d-RDF quality produced is marginal when compared to Air Force specifications, and fuel delivery rates have been lower than originally required (8000 tons/yr).

National Center for Resource Recovery Plant. This system included a full scale facility (no pelletizing) in New Orleans (now terminated) and a pilot plant in Washington, D.C. (also terminated). In general, this system includes a Trommel screening process as a pre-shredding separation step. The same types of problems existed here as in the Teledyne-operated plant; i.e., d-RDF fuel quality was inconsistent and delivery was far behind schedule. The National Center ceased operation at its Washington, D.C., plant and the organization disbanded.

Raytheon Service Corporation (RSC). This plant was built in Monroe County, N.Y., and follows the steps shown in Figure 1 for the production of d-RDF, which has recently been added as an extension of refuse-derived fuel production. Therefore, no production history is available.

Combustion Equipment Associates (CEA). This type of facility utilizes a proprietary technology for embrittling the cellulosic fraction of refuse followed by various steps to prepare the combustible fraction. The pilot plant has operated satisfactorily after much development, but CEA discontinued operations and the full-scale facility scheduled was cancelled.

Black Clawson (BC). This system is totally different; it employs a wet pulverization and separation process. A pilot plant is operating and producing pellets, but problems have been encountered with slagging in the furnaces. Though a major facility (1,500 to 2,000 tons/day) has

been constructed on Long Island, operation has ceased due to concerns about toxic emissions from the stack. Therefore, no long-term data are available on the product fuel of this system.

SPM Group, Inc. At this plant oversized materials are reduced by a coarse low horsepower shredder. A separation process on a proprietary type conveyor follows, and the product fuel is extruded into cubettes or briquettes. The Air Force at WPAFB conducted a satisfactory burn test on a 20-ton load, but the SPM pilot plant has a limited operating history.

Ames, Iowa Plant. The process used at this plant is considered a possible preliminary step to the densification step for d-RDF production in that no pelletizing is done. After instituting significant improvements and modifications performed by Midwest Research Institute, the Environmental Protection Agency (EPA), and the Department of Energy (DOE), a combination of disc screens, shredders, and air classifiers has produced a high quality combustible product ready for densification. The Ames plant produced an average of 35,000 tons of RDF per shift year. The Air Force study recommends further consideration of this process for possible incorporation into a local d-RDF plant in the greater Dayton area.

NCEL Study

NCEL sponsored a study (Ref 3 and 4) which included the identification of commercial systems (100 to 300 tons/day of d-RDF production) and product characteristics. The following summarizes the findings.

Bio-Solar R&D Corporation (Woodex). The Bio-Solar R&D Corporation has licensed Woodex, Inc., to produce a densified fuel, commonly known as Woodex, which is manufactured from organic fibrous materials through a patented process. Apparently, the first step in the system includes a compression step whereby the moisture content of the fuel is reduced to about 25%. The material is then pulverized and the moisture content is further reduced. Moisture removal is followed by densification under "extreme pressure."

Woodex, Inc., operates a plant in Brownsville, Ore., and is capable of producing between 250 and 300 tons of fuel per day. The cost for purchasing the feedstock and producing the pellets was purported to be about $15/ton in 1979.

Product Characteristics	Description or Value
Cylindrical shape	1/4 in. diam x 3/4 in. long
Specific gravity	1.3 g/cc
Bulk density	35 lb/ft^3
Net heating value	8,340 Btu/lb

Guaranty Fuels, Inc. (ROEMCC). The main steps in this type of fuel production are drying, size reduction, densification, and cooling. A portion of the feedstock is used to fuel the processing plant.

One ROEMCC plant operates in Stillwater, Minn. The plant is capable of producing approximately 40,000 tons of densified fuel per year. The fuel is sold at about $26/ton.

Product Characteristics	Description or Value
Cylindrical shape	3/8 in. diam
Pellet density	1.14 g/cc
Bulk density	43 lb/ft^3
Moisture content	15% (maximum)
Heating value	8,000 Btu/lb (as received)
Ash content	less than 5%

LeHigh Forming Co. (The Palmer Process). This process has been designed to process municipal solid waste. The unit processes include (1) magnetic separation, (2) air classification, (3) size reduction, and (4) densification.

Estimated cost for a plant capable of processing 52,000 tons of waste per year is about $3.5 million. Operating and maintenance costs can range from $12 to $60/ton, depending upon the quantity of material processed.

A pilot plant capable of processing 10 tons of refuse per hour has been operated in Easton, Pa., for the last 5 years.

Product Characteristics	Description or Value
Cylindrical shape variable diameter typical	5/8 in. diam
Pellet density	1.3 g/cc
Bulk density	35 lb/ft^3
Heating value	7,000 to 11,500 Btu/lb
Ash content	10 to 20%

Koppers (Sprout-Waldron Division). The main components of this process are two shredders, a dryer, pellet mills, and a cooler.

The production cost is estimated as about $22/ton at 15 to 18 tons/hr and about $26/ton at 6 TPH.

Product Characteristics	Description or Value
Cylindrical shape	1/4 in. diam x 1 in. long
Pellet density	1.1 g/cc
Bulk density	32 lb/ft^3
Heating value	7,300 Btu/lb
Moisture content	12%

PAPACUBE (Energy Cube Densifying System). PAPAC" is a process originally designed to compress shredded newsprint. pilot plant of the PAPACUBE process is located in San Diego, Calif. he overall system is divided into five unit processes: sorting, size 'uction, magnetic separation, conditioning and metering, and densific n.

Product Characteristics	Description or Value
Production rate	8 to 10 tons/hr
Shape	1-1/4 $in.^2$, 1 to 2-1/2 in. in length
Ash content	15%
Heating value (day)	7,100 Btu/lb

Energy to Produce d-RDF

Energy input requirements for the production of d-RDF are of consideration. Table 1 shows approximate energy consumption for the three prevalent processes.

d-RDF CHARACTERISTICS

Closely associated with the production of d-RDF are the resulting properties and characteristics of the fuel which must be considered for the utilization of d-RDF.

Structural Integrity

This property allows the fuel to be shipped and handled without disintegrating into smaller particles and dust. Experiments at WPAFB have shown that dust was a persistent problem during rail car unloading and in the fuel bunker serving the boiler. Health hazard potential, spontaneous combustion, and equipment maintenance are reasons enough to minimize and contain this problem. Solution approaches include:

1. Providing powered ventilation to remove the dust from the bunker area and into the boiler overfire air system or a bag house.

2. Providing mist oiling of the d-RDF as it is removed from the storage silo. This solution, however, may cause fuel jamming in the bunker because of resulting sticky surfaces.

3. Providing water or steam spray for the d-RDF with a resulting penalty in boiler performance due to the higher moisture content.

Storage

At WPAFB, two storage techniques were used. First, a coal silo was set aside for d-RDF storage. It was found, however, that the bearing capacity of d-RDF prior to deformation was only 285 psf. Therefore, only 20 feet of the silo's 70-foot height can be used without bridging and jamming the chute. Second, outdoor storage was also explored, but deterioration of the fuel quality resulted in a recommendation that a shed be constructed over the storage area to prevent the adverse effects of inclement weather.

Heat Content

In the discussion concerning d-RDF production, the heat content ranged between 6,000 and 11,500 Btu/lb. The more time and effort that is put into the benificiation process so that the higher grade combustibles are selected, the better the quality of the d-RDF produced is. However, economics dictate that such a product would be relatively costly. It should be noted that coal has an approximate heating value of 13,500 Btu/lb and that spreader stoker boilers are designed to accommodate this type of fuel. Therefore d-RDF, with an average heating value of 7000 Btu/lb, would be blended with coal under less than full capacity conditions.

Ash Content

The ash content is an important consideration because the higher the ash content, the lower the number of Btu's delivered per unit weight of fuel and the greater the expense of removing and discarding the ash. It should be noted here that the ash content of d-RDF approaches twice as much as that of coal. Therefore, since the heat content of d-RDF averages half that of coal, the ash content of d-RDF would be quadruple that of coal.

Combustion Characteristics

In February 1982, boiler efficiency and emissions testing using d-RDF (Teledyne National product) and coal were carried out at WPAFB (Ref 5). The purpose of the testing was to quantify the differences in the boiler pollutant emissions, precipitator efficiency, and boiler thermal efficiency.

The boiler is a Keeler Rotograte overfire unit with a rated capacity of 150,000 lb/hr of steam. Design steam is 600 psi; but, during testing, steam pressure was 385 psi. The electrostatic precipitator (ESP) is a dual chamber unit designed by Precipitair.

RESULTS

The Appendix is an excerpt of Reference 5 and describes the sampling and analytical procedures used, summarizes the results, and offers conclusions and recommendations. For the purpose of this discussion, however, Table [2] (found in the Appendix) gives a summary of the tabulated results while Figures [3] through [6] (also found in the Appendix) show the flow path and sampling points of the tests.

The contractual specifications for d-RDF are summarized below:

Energy content	6500 Btu/lb (minimum) dry
Ash content	15% (maximum) dry
Moisture content	20% (maximum) as received
Bulk density	35 lb/ft^3 (minimum) as received
Fines	5% (maximum) as received
Pellet size	1/2 in. x 1 in.

CONCLUSIONS AND RECOMMENDATIONS

1. The limited co-firing tests at WPAFB has demonstrated that 100% d-RDF can be combusted in an existing spreader stoker, and with proper grate control, clinkering and ash burnout is improved with no adverse impact on the environment.

2. Per unit weight, d-RDF contains half the Btu content of coal and twice the ash content. Therefore, for 100% d-RDF firing two points must be addressed. First, the existing fuel handling equipment must be capable of delivering twice the amount of fuel; otherwise, the boiler must be de-rated. (The fuel handling equipment at WPAFB could not deliver the required fuel during the 100% d-RDF test.) Second, the existing ash removal equipment must be capable of handling quadruple the amount. This could lead to major retrofit plans if the expected utilization of d-RDF is to be 100%. Therefore, storage and handling of twice the quantity by weight of d-RDF as coal to sustain the same Btu loading and a drop of 3.5% of thermal efficiency are disadvantages.

3. The generation and accumulation of dust, especially in the storage bunkers above the boilers, is another major problem encountered with the handling of d-RDF. At WPAFB, dusting was extreme. Potential fire and explosion hazard must be considered.

4. It should be noted that the contractor (Entropy Environmentalists, Inc.) experienced difficulties in obtaining the fuel quality specified earlier. This indicates that either the specifications are too stringent or that the production method requires further refinement.

5. Storage of d-RDF in an open area is not recommended because of deterioration of fuel quality.

6. Local production of d-RDF is most desirable because long distance transportation costs can run as high as twice the cost of d-RDF production on a per ton basis.

7. The establishment of an integrated d-RDF facility to develop fuel specifications and boiler performance test programs at WPAFB or other such activity is also recommended.

REFERENCES

1. Air Force Engineering and Services Laboratory. Contract Report ESL-TR-81-59: Performance analysis of co-firing densified refuse derived fuel in a military boiler. Cincinnati, Ohio, Rycon Inc., Dec 1981.

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4. Civil Engineering Laboratory. Contract Report, Final Report: Technology evaluation for densified refuse-derived fuel specifications and acquisition. Richmond, Calif., Cal Recovery Systems, Inc., Mar 1981. (Contract No.: N68305-80-C-0033)

5. USAF Occupational and Environmental Health Laboratory. Contract Report No. 82-017EA206HEF: Boiler efficiency and emission testing using refuse-derived fuel (RDF) and coal. Research Triangle Park, N.C., Entropy Environmentalists, Inc., Aug 1982.

Table 1. Approximate Energy Requirements for the Production of d-RDF

Process	Energy Required (kWh/ton)[a]
Size reduction	17.0
Air Classification	4.0
Densification	6.3
Miscellaneous	2.7
TOTAL	30.0

[a]Of incoming waste.

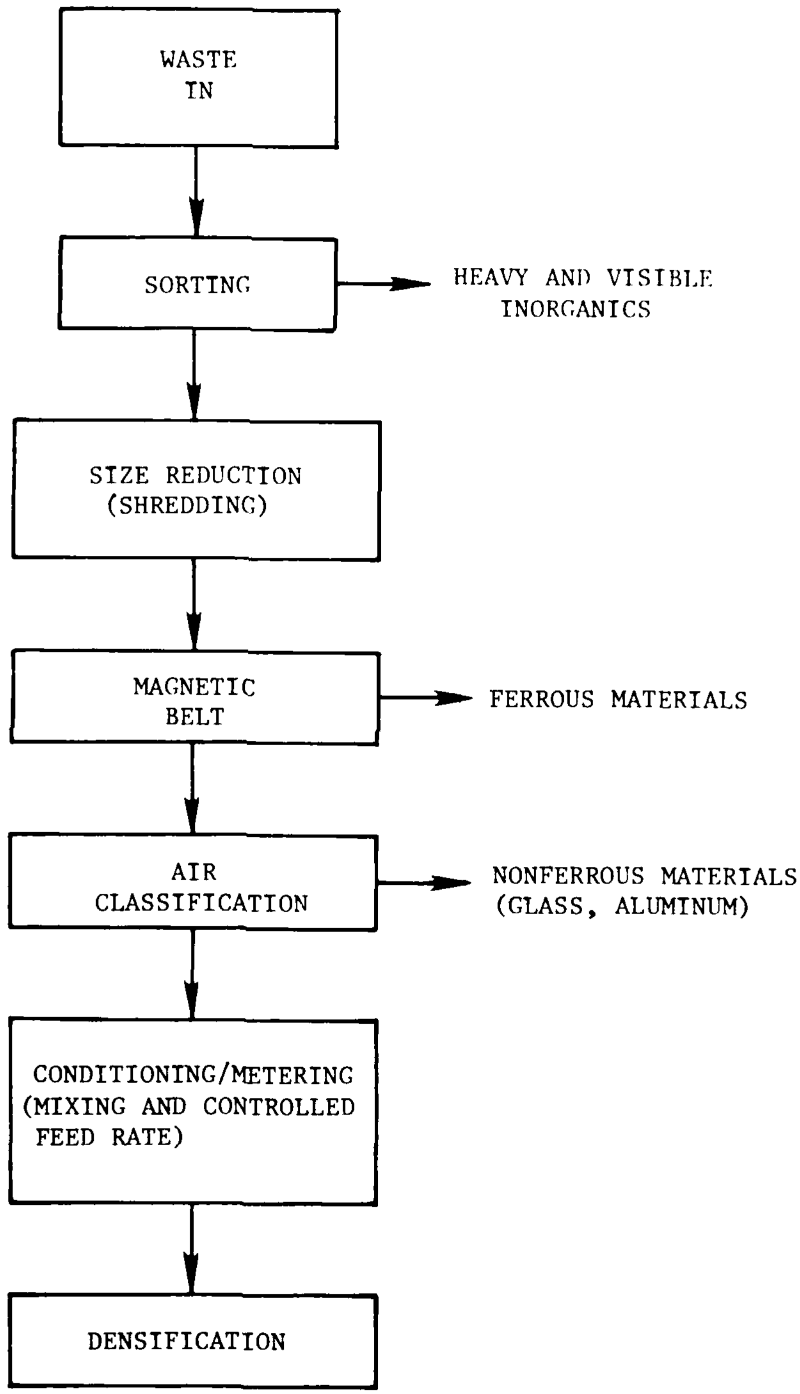

Figure 1. Typical d-RDF manufacturing process.

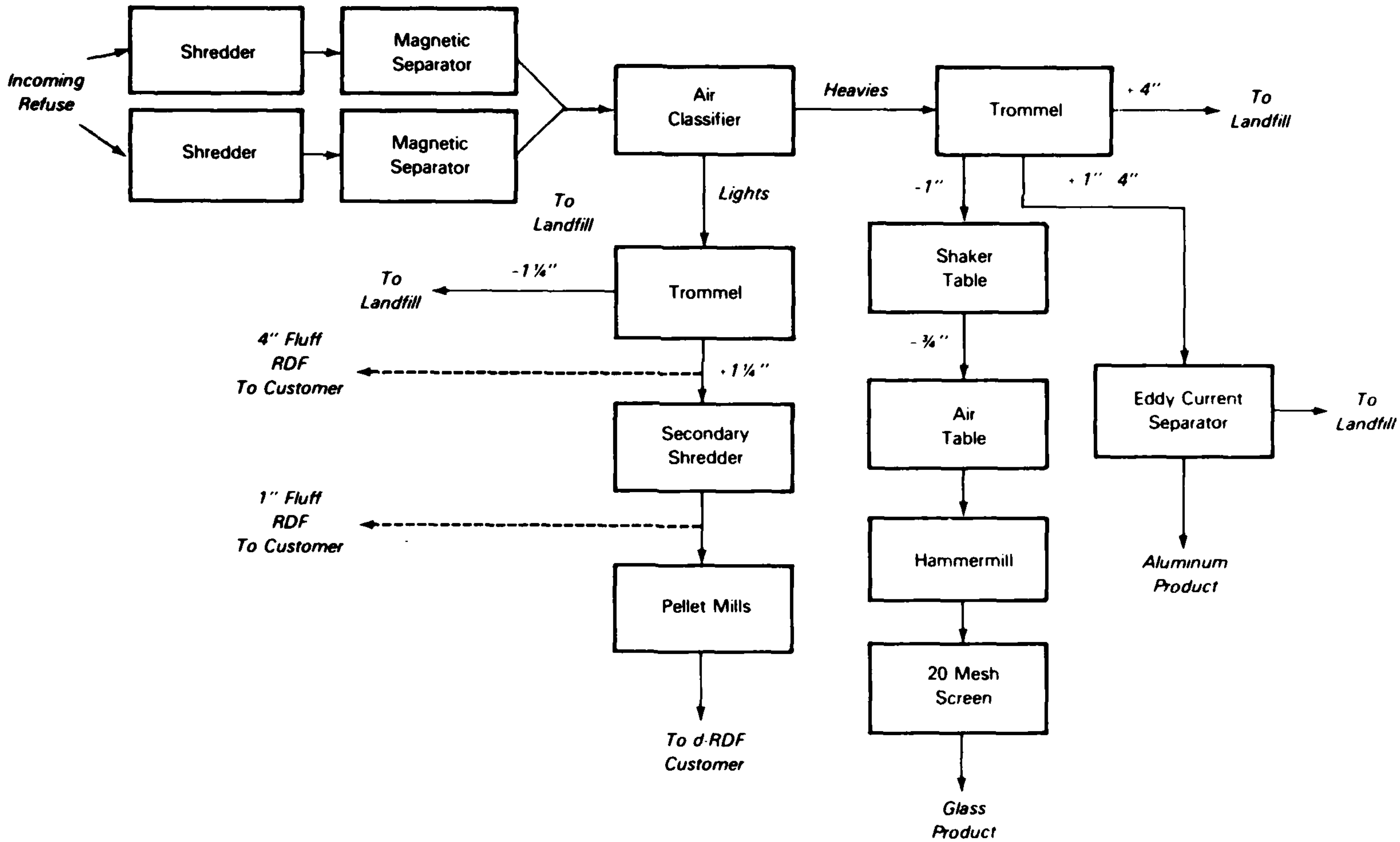

Figure 2. Process flow – Baltimore County resource recovery facility.

Appendix

EXCERPTS FROM REFERENCE 5 ON BOILER EMISSION TESTS USING d-RDF AND COAL AT WPAFB

SUMMARY OF RESULTS

The average pollutant emission results, average precipitator efficiency results, and average boiler operating efficiency results for each of the three fuel conditions, as well as the particle sizing, flow angle and resistivity tests results, are presented in Table [2].

Due to the difference in the fuel types being burned, the maximum steam loading obtainable for each fuel mix was not the same; since the boiler emissions and efficiency are affected by the loading, care must be used in comparing the results.

The "Boiler Emissions and Precipitator Efficiencies" and "Boiler Efficiency" subsections present the individual run-by-run summaries for each of the two main test objectives at each of the three fuel type test conditions. A third subsection, "Conclusions and Observations," presents a discussion and interpretation of the results. The first subsection, "Boiler Emissions and Precipitator Efficiencies," also presents the F-factor values, the results from the flyash resistivity measurements, and the flue gas flow angle data summaries.

The 40% RDF-60% coal ratio in Table [2] was calculated using the average ultimate heating values for coal and RDF in conjunction with the heating value obtained for the RDF/coal mixtures. Using this method, the estimated percent of coal making up the RDF/coal mixtures averaged 60.2% dry, by weight. Samples 1, 2, and 3 were 64.0%, 49.9%, and 66.7% coal, respectively.

Conclusions and Observations

Conclusions and observations can be grouped into two general categories: (1) the effect of the different fuel mixtures on precipitator efficiency and pollutant emissions, and (2) the effect of the different fuel mixtures on material handling systems (including boiler firing chamber maintenance) and boiler efficiency.

(1) From Table [2] it is apparent that the type of fuel mixture fired has little or no effect on the particulate collection efficiency of the precipitator. This conclusion is reinforced by the fact that the flyash resistivity remained essentially constant for the ash from all three fuel mixtures. However, the steam flow rate for the 100% RDF tests was only 66% of the steam rate for the 100% coal tests while steam load for the RDF/coal tests was 77% of that of the 100% coal tests. The collection efficiencies may or may not be similar if the steam flow rate is

held constant for all fuel mixtures. In any case, the particulate emissions are well below the limits set by the Ohio EPA (0.10 lb/MBtu), and any differences may be of little consequence. No U.S. EPA emission standards apply to this boiler since it generates less than 250 MBtu/hr. It is recommended that a constant steam flow rate be among the objectives of any further test programs.

Sulfur dioxide emissions were considerably lower using 100% RDF as opposed to 100% coal. The RDF/coal mixture showed some reduction of sulfur dioxide emissions but not as dramatic a reduction as seen with 100% RDF. This is understandable in that the RDF is shown by ultimate fuel analysis to contain a lower percentage of sulfur and sulfur compounds than the coal.

The nitrogen oxides emissions for the 100% coal tests were considerably higher than those of the 100% RDF and RDF/coal mixture tests. Since higher temperature (among other factors) increases nitrogen oxide production, this suggests that the combustion temperatures were indeed higher while firing 100% coal. This could not be verified due to the lack of necessary instrumentation.

The differences in nonmethane organic emissions between the three fuel conditions are more difficult to interpret. The 100% coal tests showed the lowest emissions while the 100% RDF tests showed an increase in emissions of approximately 70%. The RDF/coal mixture tests, which presumably would show an intermediate level of emissions, in fact revealed emissions 50% higher than the 100% RDF tests. The implication is that unknown thermodynamic conditions and/or stoichometric relationships in the boiler were affecting the nonmethane organic emissions.

Particle size analysis results showed essentially what would be expected. The mass median principle diameter at the precipitator inlet during the 100% RDF tests was 3.0 microns which is lower than expected. However, since the excess air in the boiler was much higher with this fuel than during the tests with the other two fuels, the higher excess air would have led to more complete combustion and, thereby, to smaller particles exiting the firing chamber.

(2) Using 100% RDF led to one problem associated with its low density and heat content, and another which was probably a result of its metal content.

The first problem was the inability of the material handling system to convey a large enough amount of fuel to the boiler to maintain a normal (approximately 120 to 140 thousand pounds per hour) steam flow rate. The sheer bulk of the RDF overtaxed the fuel feed conveyers and, incidentally, the counter mechanism for quantifying the amount of fuel fed. The RDF also created a large volume of fibrous dust which led to an increase in housekeeping efforts.

The second major problem is that the RDF (from visual inspection and conversations with boiler maintenance personnel) caused greater than normal slag buildup on boiler tubes and walls. This would probably lead, in the long term, to a drop in boiler efficiency and an increase in downtime for firing chamber maintenance.

It appears from the data that boiler efficiency increased when the RDF/coal mixture was fired. Again, it must be taken into consideration that the steam flow rate varied between the three fuel conditions.

Additionally, boiler instrumentation was inadequate to evaluate steam quality. These parameters could be expected to change under different steam flow rates and fuel conditions. Due to the lack of steam data, steam quality had to be assumed to be constant even though it most likely was not. The data seem to show that there are both advantages and disadvantages to the use of RDF as boiler fuel. It is recommended that these data be used in conjunction with other past or future data to determine if the fuel can be used to improve the economic and environmental performance of medium sized boilers.

SAMPLING AND ANALYTICAL PROCEDURES

All sampling and analytical procedures used were those generally recommended by the United States Environmental Protection Agency (U.S. EPA), the Ohio Environmental Protection Agency, and the American Society of Mechanical Engineers (ASME). Details of the equipment and procedures used are described in the Federal Register, August 18, 1977.

The number and locations of the sampling points were determined using EPA Method 1 [Figure 3]. The inlet and outlet ducts cross sections were each divided into 48 equal areas, i.e., 12 points on each of the four traverse axes, as shown in Figures [4] and [6] for the inlet duct and Figures [5] and [6] for the outlet duct. The centroid of each equal area was sampled for two minutes for a net run time of 96.

Velocity measurements were made according to EPA Method 2. The flue gas composition and molecular weight were determined using EPA Method 3 criteria. Particulate emissions at the inlet were determined using EPA Method 5 procedures. Outlet particulate and sulfur dioxide emissions determinations followed the procedures outlined in combined EPA Methods 5 and 8. Nitrogen oxides emissions determinations used EPA Method 7 criteria. EPA Method 25 was used in determining total gaseous nonmethane organic emissions. Particle sizing was performed using a cascade impactor sampling head attached to an EPA Method 5 probe end.

Boiler efficiency tests were performed at each condition according to ASME Power Test Code 4.1, section 4, which is the input-output method.

Flyash resistivity tests were performed according to paragraph 4.05 of ASME Power Test Code 28-1965. The flyash samples for resistivity measurements were collected at the precipitator inlet following EPA Method 5 procedures. For each condition, the filter catches for the three runs performed were combined to make one sample. In the laboratory, the test cell was filled with flyash and heated to 500 degrees F to simulate inlet duct conditions. Two readings were taken for each sample.

The F-factor value used in the calculations was determined using the ultimate analyses of the fuel samples.

All sampling equipment used was manufactured by Nutech Corporation, Andersen Samplers, Inc., or Entropy Environmentalists, Inc.

Table [2]. Average Results Per Fuel Condition

	40% RDF/ 60% Coal	100% RDF	100% Coal
Boiler Data			
Steam Load, lb/hr	115,000	97,000	146,000
Efficiency, %	82.7	75.5	75.5
Precipitator Data	grains per dscf		
Particulate Concentration			
Precipitator Inlet	0.361	0.337	0.472
Precipitator Outlet	0.011	0.009	0.014
Collection Efficiency, %	97.0	97.4	97.0
Emissions to Atmosphere	pounds per Million Btu		
Particulate	0.026	0.024	0.029
Sulfur Dioxide	0.847	0.372	0.926
Nitrogen Oxides as NO_2	0.506	0.584	0.680
Total Nonmethane Organics as Carbon	0.261	0.177	0.103
	ppm dry by volume		
Sulfur Dioxide	315	116	392
Nitrogen Oxides as NO_2	261	248	397
Total Nonmethane Organics as Carbon	519	295	231
Flyash Resistivity, ohm-cm	4.7×10^7	4.9×10^7	4.6×10^7
Yaw Angle of Flue Gas, degrees			
Precipitator Inlet	7.4	14	---
Precipitator Outlet	7.0	5.6	---
Particle Size, mass median diam.*			
Precipitator Inlet, microns	25	3.0	17
Precipitator Outlet, microns	1.1	2.1	3.6

*Taken from log-probability plot.

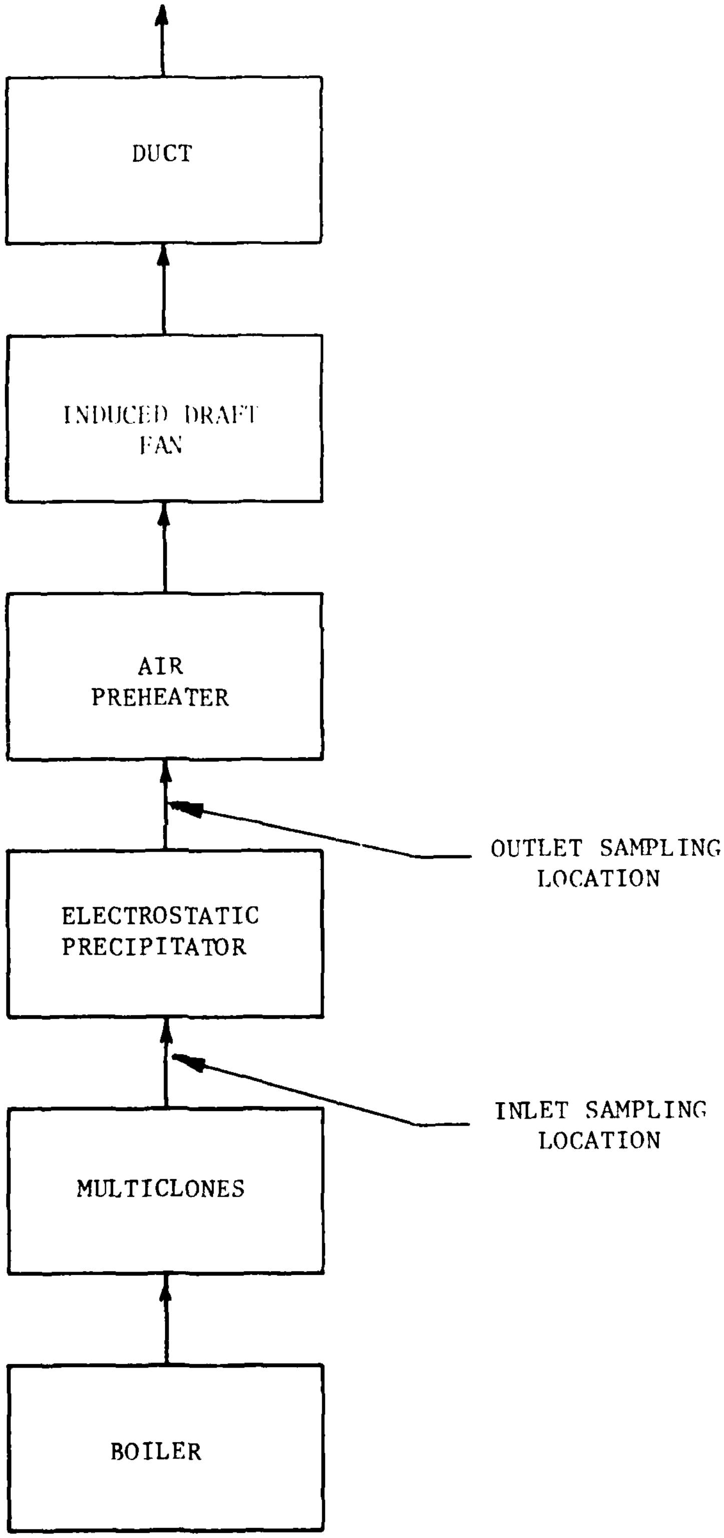

Figure [3]. Air flow schematic, showing sampling locations during testing.

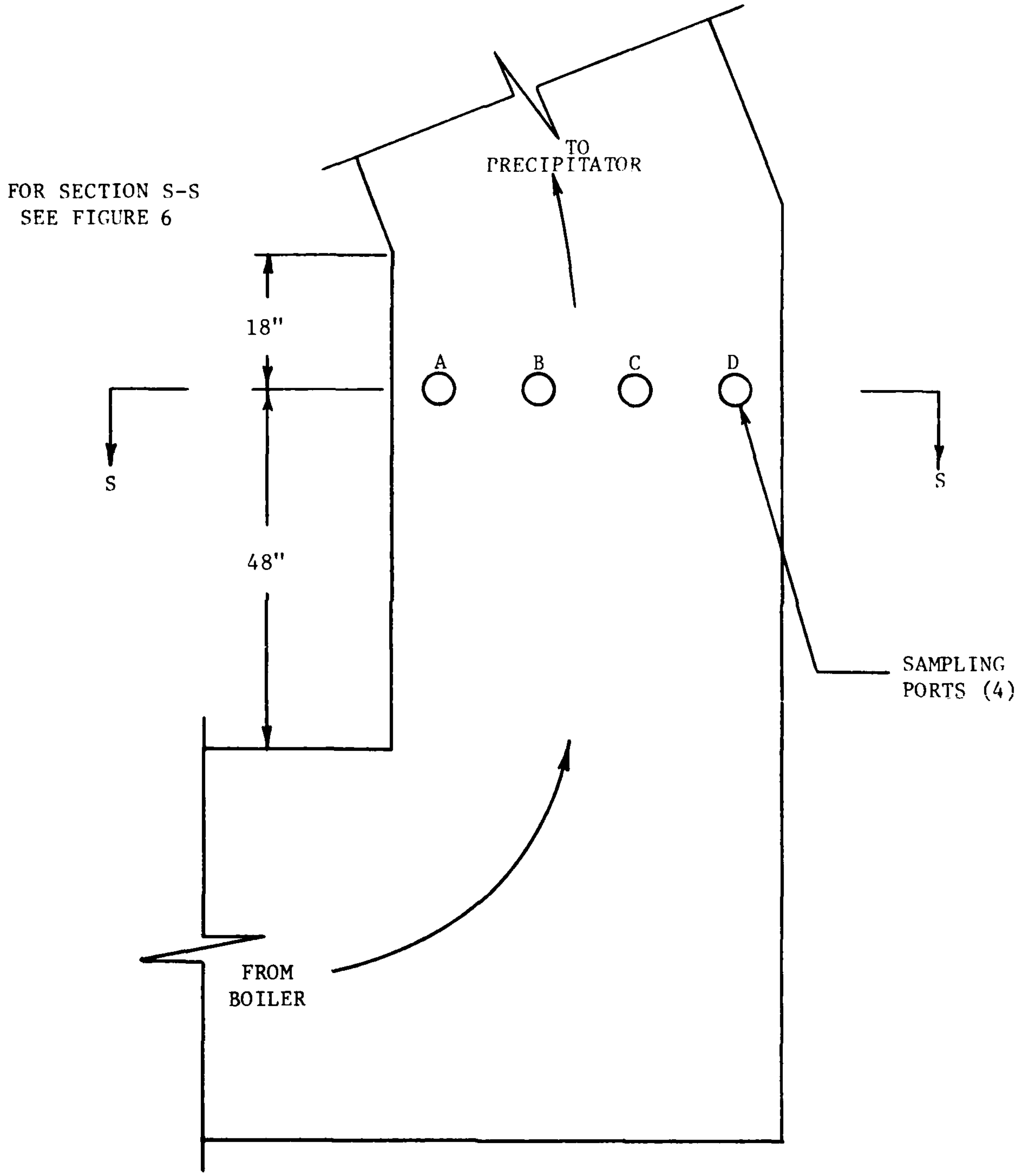

Figure [4]. Inlet duct dimensions and sampling port locations.

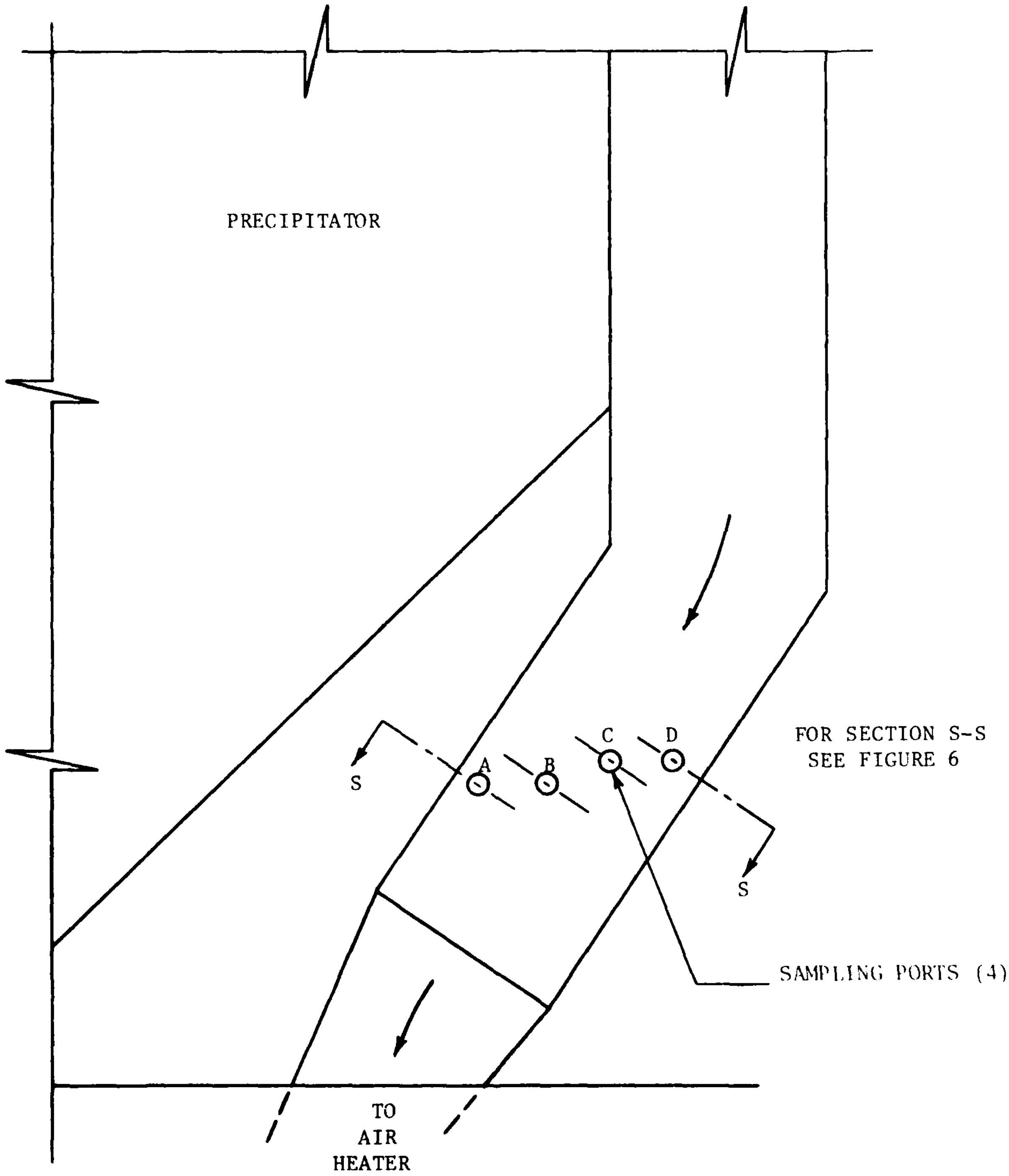

Figure [5]. Outlet duct configuration showing sampling port locations.

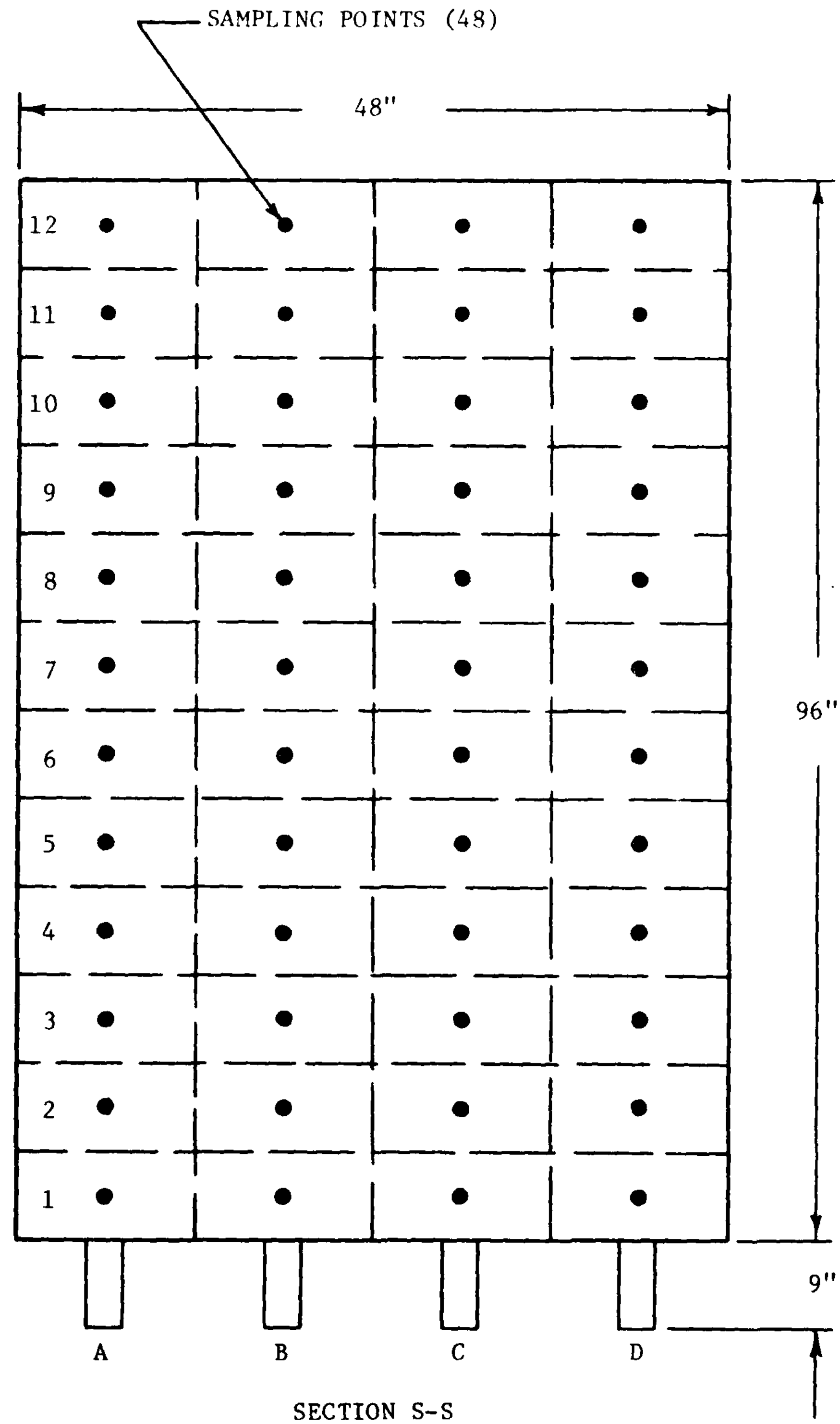

Figure [6]. Inlet duct cross section showing equal area divisions and sampling point locations.

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